Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

1
A984Mm
cop. 2

U. S. DEPT. OF AGRICULTURE
LIBRARY
MAY 5 - 1961
CURRENT SERIAL RECORDS

Improved Loading Methods for Truck Shipments of Florida Avocados and Limes

MARKETING RESEARCH REPORT NO. 456

U. S. DEPARTMENT OF AGRICULTURE

AGRICULTURAL MARKETING SERVICE
TRANSPORTATION AND FACILITIES RESEARCH DIVISION

PREFACE

Loading patterns used for containers of various perishable and fragile agricultural products determine to a large extent the degree of protection that can be afforded to the commodities against damage and deterioration during transportation. Efficient methods of stowing and securing the load can weld several hundred relatively weak and fragile containers into a strong, solid load that can withstand normal transportation hazards. All the advantages of sturdy, attractive containers and a modern refrigerated truck trailer can be nullified by loading the containers in the vehicle in such a way as to predispose them and their contents to damage or to prevent adequate refrigeration and ventilation by blocking completely or partially the circulation of air around, under, and through the load. This study, aimed at improving loading methods to provide better transportation protection for Florida avocados and limes, is part of a broad program of research of the Agricultural Marketing Service to reduce costs and improve the efficiency of marketing agricultural products.

ACKNOWLEDGMENTS

Appreciation is expressed to the various individuals and organizations whose cooperation and assistance made this study possible. Special credit is due the Florida Avocado Administrative Committee, the Lucerne Packing Company of Princeton, Fla., and the Elbert Moore truck Brokerage of Tampa, Fla., for making their products, facilities, and equipment available for this research.

CONTENTS

	Page
Highlights	4
Background of study	6
Obtaining data	7
Preliminary study	7
Test shipments	8
Results	8
Preliminary study	8
Transit test No. 1	22
Transit test No. 2	28
Conclusions and recommendations	31

March 1961

HIGHLIGHTS

A preliminary study of 25 commercial shipments of avocados from Florida to New York and Chicago during the 1957-58 shipping season revealed that many shipments arrived at destination with considerable shifting and disarrangement of the load and with varying amounts of spoiled and overripe fruit. It was found that the following major deficiencies in containers, handling, and loading methods contributed in a large measure to the losses:

1. Loading lots of precooled and nonprecooled fruit together in the same vehicle.
2. Permitting pallet loads of precooled fruit to stand on open loading docks in warm weather for a half hour or more before loading into the vehicle.
3. Failure to precool trailer before loading, and to use canvas curtains over rear door opening to prevent loss of cool air during loading.
4. Using containers with varying outside dimensions for mixed shipments of avocados and limes. This made it impossible to use load patterns incorporating continuous longitudinal air channels for unobstructed flow of refrigerated air through the load.
5. Failure to use adequate stripping on the layers of containers in the load. This permitted containers to shift out of row alinement and block air circulation through the load, thereby preventing effective refrigeration.

After completing the preliminary study, workers on the project recommended to the Avocado Administrative Committee that the outside dimensions of the avocado and lime shipping containers be revised in such a way that the containers would fit into modular units with common outside dimensions but would retain their present capacities. This would make it possible to load containers of different capacities in the same truck and to provide unobstructed channels for the continuous circulation of refrigerated air around the fruit. Dimensions of the most widely used shipping containers, except the lime pony flat, have since been revised so that their outside dimensions conform somewhat more closely to those of the suggested modular unit.

After some experimentation with alternative loading patterns in which the rates of airflow through air circulation channels of prototype loads were measured in a closed trailer, a new pattern was developed and was tested in a shipment from southern Florida to northern markets during the 1959-60 shipping season. The pattern provided for continuous circulation of air through channels between the rows of containers which extended the entire length of the load. Adequate clearance between the last stack in the load and the rear doors was provided to permit the refrigerated air from the front of the trailer to flow back through the longitudinal air channels that opened on the rear of the load. The rear stack was prevented from shifting backward against the trailer doors and blocking air circulation by placing two sections of wooden floor racks between the rear stack and the doors. The containers throughout the load were held in row alinement by: (1) Nailing light crosswise wooden strips on every third or fourth layer of the wooden avocado flats, (2) nailing vertical and diagonal wooden strips to the wooden flats in the rear stacks, and (3) capping the lower layers of the load stacked 6 cartons wide with a stabilizing top layer 7 cartons wide in tight contact with the side walls of the trailer.

Inspection of the load during transit and upon arrival at northern markets revealed little or no shifting or disarrangement. Thermocouple temperature readings taken in 20 places in the load during the entire trip showed rapid initial cooling of the fruit and maintenance of favorable fruit temperatures from loading time until delivery of the fruit to the consignees. Inspection of the fruit at time of unloading showed it to be firm ripe and in good marketable condition.

The control shipment contained the same variety of avocados, which were packed in the same type of containers at the same packinghouse, shipped in an identical trailer to the same markets, and carefully loaded by the best conventional pattern then in general use. This shipment showed: (1) Considerable shifting and disarrangement of the load, and blocking of air circulation channels a short time after the truck left the shipping point, (2) much higher fruit temperature during most of the trip and upon arrival at destination markets, and (3) overheating and overripening of the fruit, which resulted in reduced prices for part of the fruit and some dumping.

After completion of these shipping experiments, the cooperating shipper adopted the new loading pattern for all his truck shipments of avocados. At the close of the 1959-60 shipping season he reported the almost complete elimination of load shifting, disarrangement, container damage, and overheating and overripening of his fruit in transit.

IMPROVED LOADING METHODS FOR TRUCK SHIPMENTS OF FLORIDA AVOCADOS AND LIMES

By Russell H. Hinds, Jr., and Philip L. Breakiron, transportation economists,
Transportation and Facilities Research Division
Agricultural Marketing Service

BACKGROUND OF STUDY

Avocado and lime production in Florida is centered about 30 miles south of Miami in the Homestead area, except for a smaller producing district to the northwest near Lake Placid. Production of avocados increased from about 33,000 bushels in the 1930-31 marketing season to more than 500,000 bushels in the 1955-56 season. 1/ Lime production also increased from an average of about 56,000 bushels in the 1920's to 266,000 bushels in the 1956-57 season. 2/

Growers usually produce both avocados and limes, and shippers generally pack both kinds of fruit in the same vehicle, though usually in containers of different sizes. About 95 percent of the Florida avocado and lime crops are transported to market by motortruck. Many shipments consist of both avocados and limes in the same vehicle, while in other shipments either or both commodities are loaded along with tomatoes, cucumbers, peppers, and other vegetables produced in south Florida. Both fruits are therefore frequently exposed in transit to various environmental conditions unfavorable to protection of their inherent quality. Both fruits are subtropical and have the same general temperature and humidity requirements. Because both fruits require about the same protection during transportation, the results of this research on transportation of avocados apply also to the transportation of limes.

Shipping losses for limes are reported to be relatively light, but transportation losses for avocados are estimated at about 5 percent of the crop value. Most of these losses are in spoiled and overripe fruit at destination markets. The monetary losses sustained in transportation of avocados and limes are difficult to determine as no data on losses and damage payments are published by any organization. Interviews with truckers and receivers, however, have disclosed that claims for losses in individual shipments of avocados range as high as $1,500, averaging about $30 per shipment. On this basis, losses are estimated to amount to about 5 percent of the market value of the fruit. Using an average market value of the Florida crop for the 6-year period 1952-57, it is estimated that the losses averaged $64,000 per year. Not all these losses may be the direct result of transportation problems covered in this study. However, these estimates do not include losses from reduced shelf life, deterioration, and overripeness in subsequent marketing channels which may be partly due to inadequate refrigeration during transportation.

1/ Ruehle, George D. The Florida Avocado Industry. Univ. Fla. Agr. Expt. Sta. Bul. 602, 100 pp., (illus.). Nov. 1958.

2/ Florida State Marketing Bureau and Florida Department of Agriculture. Annual Agricultural Statistics, 1958-59 Season. 203 pp. Nov. 1959.

The marketing of avocados and limes grown in south Florida has been covered by a Federal marketing agreement and order since the 1954-55 shipping season. Under this agreement the growers' and shippers' Avocado and Lime Administrative Committees have adopted regulations governing not only the quality, size, and grade of the fruit marketed from that area, but also the sizes and capacities of the various types of containers used for shipment.

These regulations covering sizes and dimensions of containers were adopted by the committees in order to stabilize trading conditions by reducing the multiplicity of sizes and types of containers used. To determine which of the various sizes and types of containers in use at the beginning of the marketing agreement were best suited for marketing avocados, the Avocado Administrative Committee requested the Agricultural Marketing Service (AMS) to evaluate the containers. In the 1956-57 avocado shipping season, 60 test shipments of 6 standard and 2 nonstandard types of containers were studied. 3/ This study showed that all 8 containers gave generally satisfactory results when properly used. It was concluded from the study that careful packing of fruit in the containers and improved methods of loading the containers for shipment would materially reduce the amount of physical damage to the fruit and the containers, provide more adequate protection of product quality during transportation, and prolong shelf life of the fruit. This led the Avocado Administrative Committee to request AMS to conduct additional research to develop improved loading and transportation methods for the fruit. These methods are described in this report.

OBTAINING DATA

To familiarize the research workers with the methods employed in shipping avocados by truck, to determine the nature and the scope of the transportation problems, and to develop the data necessary for planning subsequent shipping tests, a preliminary study of 25 truck shipments was made during the 1957-58 marketing season. As a result of this preliminary study, certain changes recommended to the Avocado Administrative Committee were made in the outside dimensions of most avocado containers. These changes took some time to effect. Meanwhile, however, a severe freeze in south Florida during the winter of 1957-58 extensively damaged the avocado and lime groves and destroyed most of the 1958-59 season's crop. The shipping tests scheduled for the second phase of the study had to be deferred until the 1959-60 shipping season.

Preliminary Study

The preliminary study in 1957-58 covered handling and loading methods at shipping points for 10 shipments and arrival condition of 15 truck shipments at terminal markets. Observations were made at the packinghouses on the various methods of packing and precooling the fruit for shipment. The fruit was examined to determine condition and firmness, and sample pulp temperatures were taken. The loading of regular commercial shipments was observed and photographed.

3/ Fountain, James B., and Stokes, Donald R. Evaluation of Shipping Containers for Florida Avocados. U. S. Dept. Agr. Mktg. Res. Rpt. 228, 24 pp., (illus.). May 1958.

At destination markets the arrival condition of loads was studied. Load disarrangement and the number, size, and completness of ventilation channels were observed. The amount and type of container damage, fruit bruising, degree of firmness, and pulp temperatures were also noted. Truckers and receivers of the fruit were interviewed as to prevailing transportation methods and arrival condition of the fruit.

Test Shipments

At the beginning of the experiment early in the 1959-60 shipping season, several loading patterns were laid out in trailers used for regular commercial shipments. The last several stacks were left off the rear of the load, and the rate of air flow through the load channels in the stationary trailer with the mechanical refrigeration unit running was measured with a vane anemometer. The pattern which had the highest rate of air circulation was the one chosen for road testing.

Two over-the-road shipments with avocados of comparable condition and maturity were made from the same shipping point to the same destination during a 2-week period in October and November 1959. In one shipment the experimental load pattern was used; the other shipment served as a control. Outside temperatures were about the same throughout this 2-week period. The fruit used in both the control and the test shipments was of the same variety, packed in the same types of containers in the same packinghouse, and shipped in trailers of the same model and type. The fruit used in both shipments was handled in the same way and exposed to almost identical preshipment temperatures. The observer rode in the tractor cab of both shipments from shipping point to destination, taking temperature readings in 20 places in the load 12 or 13 times during transit. Thermocouples were placed in sample fruits in different types and sizes of containers in different load locations. The observer took temperature readings on a potentiometer in the cab of the tractor to which the thermocouple cable extended from the trailer.

Upon arrival of the test and control shipments at destination market, the observer noted the condition of load and of the containers. He also examined the fruit in various types and sizes of containers in different load locations.

RESULTS

Preliminary Study

In the shipments observed during the 1957-58 shipping season the avocados were handled with a reasonable degree of care in packing and in preshipment storage. Practically all fruit was found to be hard ripe and not easily bruised at the time it was packed. Some fruit was precooled in temporary storage before shipment and some was loaded directly into the trucks without precooling.

In many shipments consisting of both avocados and limes from two or more packinghouses, some lots were precooled while others were not. In other instances, particularly when supplies of both avocados and limes were limited, the fruit was shipped in the same trailer with nonprecooled lots of tomatoes, peppers, and cucumbers. In such shipments the precooled lots of fruit picked up considerable heat from the nonprecooled lots. The multiplicity of shapes, types,

and sizes of containers in the mixed loads made it virtually impossible to build a load with continuous ventilation channels throughout its length to facilitate cooling of the fruit.

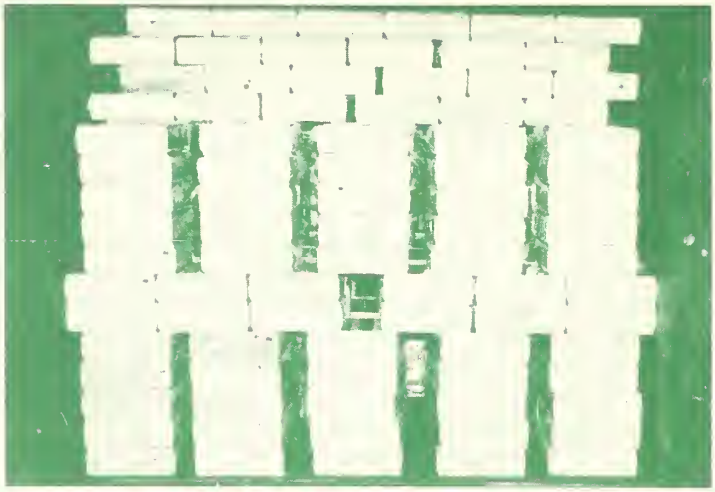
Avocados were packed in two general types of containers made of either wood or fiberboard. One was a flat and the other a 4/5-bushel box. These containers did not have a common dimension either in length or width and when stacked with limes, their companion product, a third size of container (pony box) was added. This variation of sizes made it impossible to follow a standard loading pattern on less-than-truckload shipments. On straight loads of containers of only one size, many shippers attempted to maintain some type of stacking pattern to provide circulation around and through the load. However, most of the avocados leaving Florida do not move in this way but rather in less-than-truckload (l.t.l.) shipments of limes and avocados in mixed sizes of containers. Oftentimes a single truck carried small orders from several shippers to as many as four or five northern markets. In such situations one packinghouse would load its portion of the truck with a good stacking pattern of one size of container, only to have that pattern rendered ineffective at a subsequent packing shed by a second or third size of container stacked in still a different pattern. Figure 1 shows the variation in container sizes and load patterns found in one truck. These factors, coupled with the additional problem of combining precooled and nonprecooled fruit in the same truckload, represented some of the major transportation problems facing the Florida avocado industry at the shipping point.

Most of the truck operators who haul avocados do so regularly and are generally familiar with the temperature requirements of the fruit. Truckers interviewed in this survey related their difficulties in making successful deliveries and said they frequently received claims from shippers for unacceptable fruit at destination. Some felt that many of the claims were unfounded in that prevention of such losses of fruit was beyond the control of the trucker. The most common difficulties experienced by the truckers covered in this limited survey were:

1. Boxes of overripe fruit (soft, or about to become soft) being mixed with other boxes of hard green fruit.
2. Temperature of the fruit when presented for shipment was often very high, even when supposedly precooled.
3. Precooled and nonprecooled fruit were mixed in the same load.
4. Containers of various sizes and shapes and mixed produce were placed in the same load.
5. Trucks often carried a large number of l.t.l. shipments in one load with two or more destinations so widespread that final delivery was not completed for as long as 5 days.

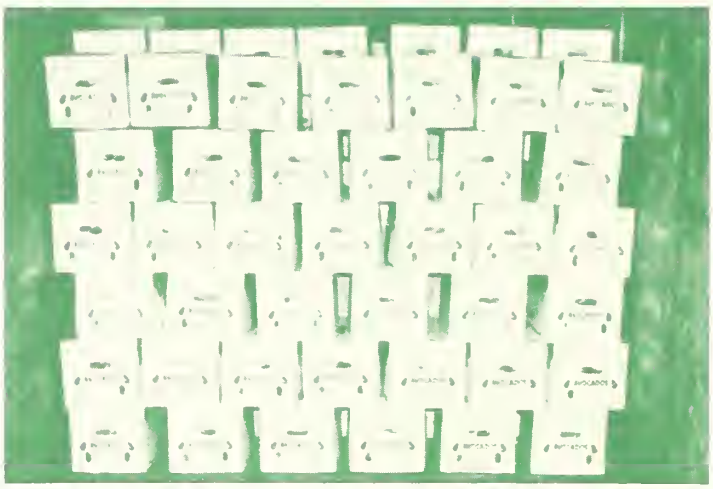
Some of the packing sheds handling avocados were equipped with refrigerated rooms for precooling and for preshipment storage of the fruit, while others were not. The avocados which are not refrigerated are generally shipped within 3 days, whereas other sheds operating cold rooms often extend their holding periods up to 7 days. Commercial storage of avocados is not generally practiced in south Florida. However, under good conditions, most of the more popular varieties can be held under refrigeration 2 to 4 weeks before ripening. 4/

4/ See footnote 2, page 6.



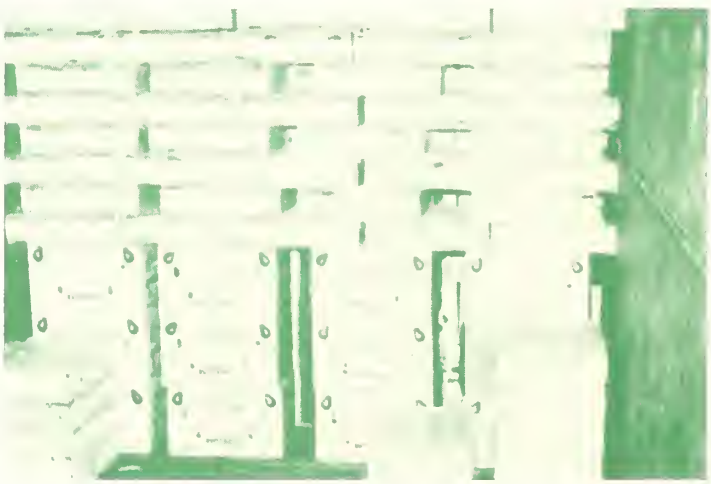
A

BN-11712



B

BN-11713



C

BN-11714

Figure 1.--Typical load patterns for conventional mixed shipment of avocados consisting of several less-than-truckload lots of containers of different types and sizes: (A) Wooden avocado flats, (B) 4/5-bushel fiberboard avocado and lime boxes, (C) avocado flats loaded on top of the 4/5-bushel box.

About 50 varieties of avocados are grown commercially in Florida, most of which can be offered for shipment in good condition when properly handled, packed, and precooled. A few of the early-maturing West Indian varieties, however, ripen very rapidly and must be cooled and shipped as soon as possible after picking.

Since the avocado will ripen rapidly when not properly refrigerated, it is essential to take full advantage of the available refrigeration at all times. It was noted that pulp temperatures of some precooled fruit offered for shipment varied as much as 15 degrees between the containers in the center and those on the outside of the palletized storage and handling units. This fruit had been in the cold storage room for 24 hours but was tightly stacked, making it impossible for the fruit in all containers in the unit to become uniformly cooled. Figure 2 shows a stacking pattern for palletized units of the 4/5-bushel fiberboard box now used by one packinghouse which formerly experienced wide temperature variations in tightly stacked palletized units. This packer reported that pulp temperatures of his fruit are uniform since adequate circulation around each container on the pallet has been provided.

Once the fruit is cooled, it is important to keep its temperatures within the acceptable range of 50°- 55° F. for most varieties to prevent rapid ripening, which reduces shelf life of the fruit and makes it more susceptible to bruising. Raising the fruit temperature above this level for even short periods of time speeds up the ripening process. It is often difficult to remove the heat from the fruit after it has been loaded in the vehicle. This is especially true of heat gains by precooled fruit during the loading of the truck in hot weather. The truck refrigeration units are generally designed to maintain the air temperature inside the van at a given level, with some reserve for cooling the product. However, in hot weather many units do not have sufficient capacity to do more than remove the heat which infiltrates through the truck insulation. For this reason, precooling before shipment and avoiding heat pick-up at loading time are recommended as the first necessary steps in holding the fruit at, or near, desired levels during transit.

During this study the practices of loading crews were observed. In one instance a forklift operator kept two or three palletized units of containers on the loading dock at all times so as to be well ahead of the stacking crew. Some of these pallet loads remained on the dock for as long as 50 minutes during which time the temperature of the fruit in the containers on the perimeter of one pallet load rose 12 degrees before the containers were stacked in the vehicle. Throughout the entire loading operation this heat gain continues whenever the air temperature is higher than the product temperature. A curtain of plastic film, canvas, or similar material over the rear door opening of the truck is an effective means of preventing excessive loss of cool air from the trailer during loading. 5/

Precooling the trailer by operating the refrigeration unit with the doors closed for about an hour before loading is also recommended. The doors should also be closed to prevent loss of refrigeration whenever there is more than a 15-minute delay during loading. This may seem a nuisance to the loading crew

---

5/ Guilfoy, Robert F. A Curtain to Help Maintain Temperatures in Local Refrigerated Delivery Trucks. U. S. Dept. Agr. Mktg. Res. Rpt. 176, 21 pp., (illus.). May 1957.

BN-11715

Figure 2.--Stacking pattern used in cooler for maximum circulation of air around each container.

and driver, but the heat pick-up during a one-hour break for lunch may be sufficient to raise the temperature of most precooled fruit in the entire load as much as 10 degrees.

Preshipment observations also disclosed that no shippers required their personnel to make a careful inspection of the truck and refrigeration equipment before loading was commenced. Compromises must sometimes be made because of lack of time, but the necessity of sufficient refrigeration in transit makes basic inspection of the truck equipment essential. Of foremost importance is the refrigeration unit, either mechanical or ice bunker and blower. The operation of this item should be checked before loading. The thermostat on a mechanical unit should be adjusted above and below the existing inside temperature of the trailer to ascertain its proper functioning and ability to cycle the unit. Floor racks should be examined to see that the stringers run lengthwise of the trailer. In one instance preshipment observations revealed that the removable racks were being placed with the stringers running crosswise in the trailer, completely blocking the circulation of air under the load. Several instances were also noted in the preshipment survey where grooved floors for air circulation under the load had not been thoroughly cleaned before loading. The dirt and debris effectively blocked the circulation of air through the grooves. When the trailers are so equipped, the grooves should be free of trash or dirt from front to rear. Debris often accumulates at the front of the trailer in the last inch or two of the grooves, where it is not readily removed by sweeping. It is not uncommon to find trailers with half of the grooves blocked where they meet the ice bunker wall or bulkhead. When such conditions exist, the circulation under the load is reduced proportionately.

Preloading inspection may depend largely on the shipper's previous experience with a particular trucker. The shipper may know from past experience that a certain trucker would not present a vehicle for loading unless it was thoroughly checked and in good operating condition. In such instances equipment inspections may not always be necessary. If an itinerant trucker is hired, however, thorough inspection of the equipment is recommended, and the following items should also be checked:

1. General tightness of body and doors to prevent air leakage.
2. Existence of odors from previous loads which may be absorbed by the commodity.
3. Condition of tires and presence of spare.
4. Adequate cargo insurance.
5. Proper licenses and permits for States to be traveled.

Although it may be the responsibility of the trucker to see that his equipment is clean and well maintained, preloading inspection is one of the most important steps that a shipper can take to assure himself that his produce is being properly cared for and is likely to be delivered in good condition and on schedule.

In the study of shipments upon arrival at the New York and Chicago markets, receivers indicated that rejections of shipments were most frequently made in warm weather and were based largely on overripeness, which they felt was partly due to improper refrigeration. Observations of incoming shipments made during cold weather revealed that most pulp temperatures were generally satisfactory. One truck shipment inspected had been loaded at three packing sheds with a total of six l.t.l. orders. Boxes of various sizes were scattered throughout the load in an irregular pattern, blocking most of the circulation and making complete and effective refrigeration impossible. Temperatures 10 to 15 degrees above the desired 50° F. level were found within the loads in those areas where the containers were so stacked as to block free airflow. Although the outside temperature at destination at this time was 10° F., the fruit arrived warm. Had the weather been hot, losses probably would have been serious.

Loads had shifted to some extent in most of the truck shipments of avocados arriving at the New York and Chicago markets. This movement was most prevalent at the rear of the truck in the last three or four stacks. Some trailers have a long overhang behind the tandem wheels. Vertical vibration is concentrated in this area of the trailer body, and most of the damage to containers and product was found there. There was also considerable movement of the containers in the center and front of some loads, caused by poor stacking, improper bracing, or "cowboy-type" driving by the operator. Shifting varied from complete disarrangement of the stacking pattern in some loads to only slight movement in others. In about half of the trucks inspected, enough containers shifted out of row and stack alinement to partially block the circulation of refrigerated air. Most of the loads were not secured at the rear of the trailer to prevent containers in the rear stacks from shifting backward against the door. When the load shifts backward against the rear doors, circulation at that point is partly or completely blocked, depending on the pattern. This may adversely affect the temperature of the fruit in the entire load.

Most of the containers, except for those in the two or three bottom layers of the load, arrived with little external evidence of damage. Overhead weight of the load did cause creasing of the fiberboard containers in the bottom layers to such an extent that the number of fruit in the box could be counted by the imprint of it on the cover. The hard green fruit sustained no apparent damage from this overhead weight, but the soft fruit was severely bruised and sometimes crushed.

Effect of Container Dimensions on Load Patterns

The lack of common outside dimensions for the 4/5-bushel boxes, the fiberboard and wooden avocado flats, and lime ponies made it impossible to devise suitable loading patterns for shipments containing more than one size of container. Recognition of the basic problem in this phase of the study led AMS to recommend to the Avocado and Lime Administrative Committees that the overall outside dimensions of the containers be temporarily adjusted to fit into a modular unit so that additional research could develop improved loading patterns. Adjustment of container dimensions in such a way as to retain about the same capacities was possible as the 4/5-bushel fiberboard box is jumble packed and an offset pattern is used for packing the fruit in the avocado and lime flats.

The purpose of the modular unit shown in figure 3 is to make it possible to stack containers of various capacities together in the same load and maintain rows of uniform widths. This in turn, makes it possible to use a load pattern with continuous ventilation channels running from the front to the rear of the trailer.

In the recommended modular unit two lime ponies placed crosswise of the unit are approximately equal to the outside dimensions of the avocado flat, which, in turn has the same basal dimensions as the 4/5-bushel fiberboard box. To facilitate effective cooling of the fruit in cold storage rooms and in transit, it is necessary for the containers to have sufficient ventilation openings. The modular containers shown in figure 3 are designed to fit into a loading pattern with the continuous ventilation channels running along the long side of the unit. For this reason the ventilation openings are placed on the sides of the 4/5-bushel fiberboard box and the avocado flat and on the ends of the lime ponies. The dimensions of the hypothetical modular unit shown in figure 3 conform as closely as possible to outside dimensions of containers in use at the time this study was made.

The modular unit plan for standardizing outside dimensions of containers to facilitate the use of more efficient loading patterns was recommended to the Avocado and Lime Administrative Committees at the close of the preliminary study made during the 1957-58 shipping season. The dimensions of three sizes of avocado flats were subsequently changed by the Avocado Aministrative Committee in such a way that their outside dimensions conform somewhat more closely than previously to those shown for the suggested modular unit. The dimensions of the lime pony flat have not yet been revised. Container standardization is therefore not yet an accomplished fact in the Florida avocado and lime industries. However, by the beginning of the 1959-60 shipping season enough progress had been made in this direction to permit testing of a new continuous-channel load pattern specifically designed for a modular unit of containers of different capacities.

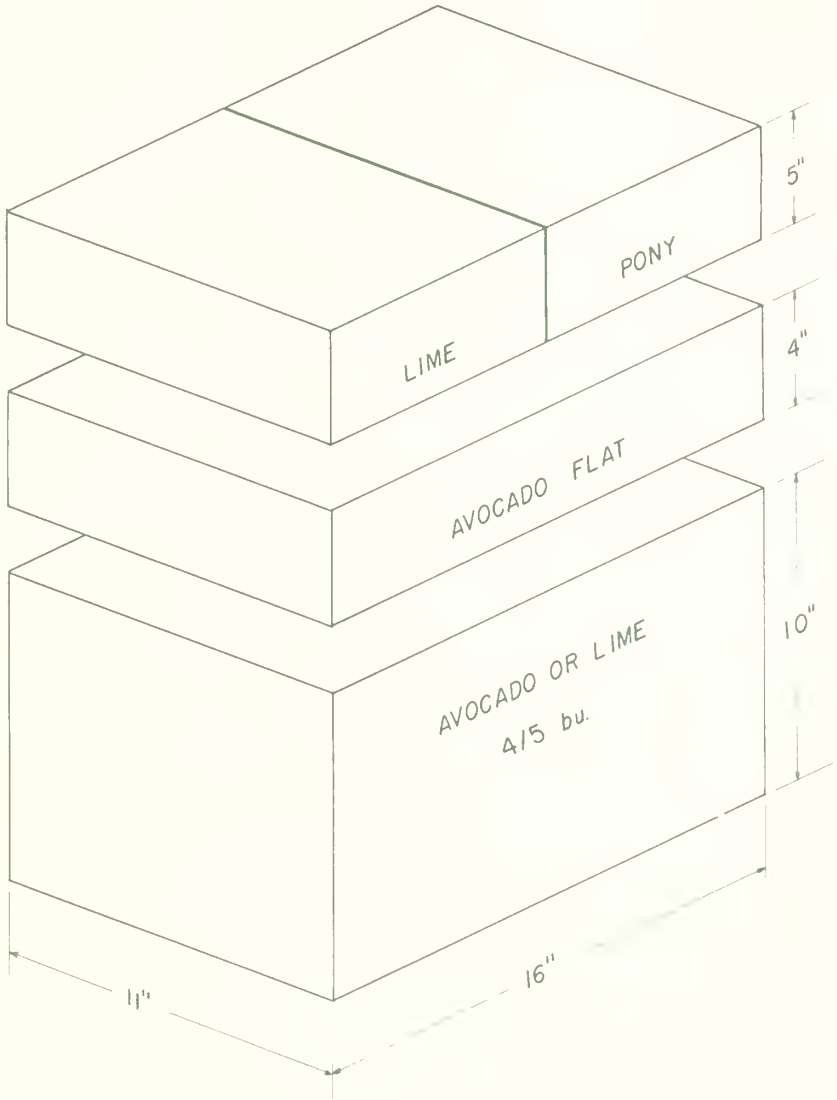


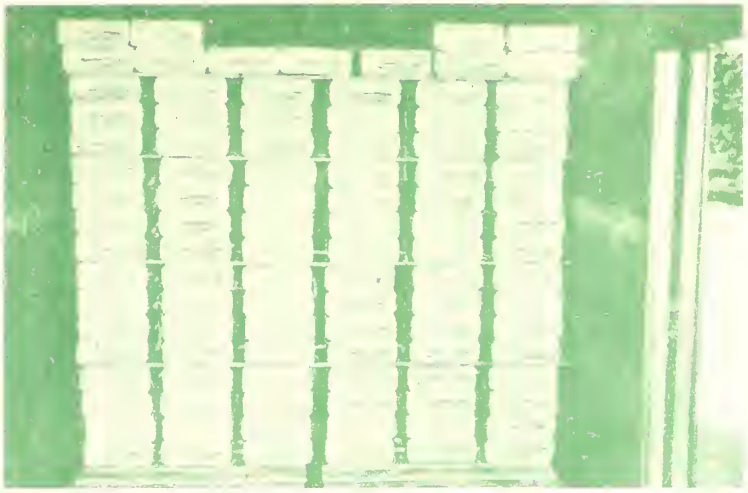
Figure 3.--Avocado and lime containers with modular dimensions.

Development of Improved Loading Patterns

In designing improved load patterns that might facilitate more adequate refrigeration of avocados and limes in transit than those found to be in general use in the preliminary study during the 1957-58 shipping season, the following basic facts concerning air circulation and refrigeration were taken into account. First, warm air rises and cold air settles. Second, circulating air follows a path of least resistance. Third, circulating air can only remove heat during its flow cycle if it passes through the source of the heat and then to the cooling coils or ice for removal of the heat picked up during its circulation through the load. On these basic principles, several such patterns were developed for testing in commercial shipments of avocados during the 1959-60 shipping season.

Figure 4 illustrates a basic design for the avocado flats, 4/5-bushel boxes, and the lime ponies which proved satisfactory for the size of containers in use at that time. Each of the six rows is bordered on both sides by air channels which supply refrigerated air. The containers were held in row alinement by ½" x 1" wood strips placed between layers. These strips touched the walls alternately on opposite sides to help prevent the entire load from shifting tight against the trailer side wall. The containers must be kept from touching the wall as this is one of the main sources of heat which infiltrates the lading area during transit. It would be more desirable to have the side walls stripped for this purpose, but many trucks are not so equipped. Some shippers use an alternative method in which 7 tightly stacked boxes are substituted for the wood strips on every fourth layer. However, this pattern divides each of the seven circulation channels into three or four smaller channels, causing some additional restriction to the flow of refrigerated air through the load. Moreover, the seventh box must be left out of the first stack at the ice bunker wall or bulkhead; otherwise all of the channels will run to a dead end and the return of air through the load channels to the cooling unit will be blocked. Although this particular pattern eliminates the cost of crosswise stripping and helps to stabilize the load, it should only be used with straight loads of wooden containers which are well ventilated. Both the fiberboard flat and the 4/5-bushel box may be subject to overheating when the stabilizing layer is used in lieu of stripping, since they do not have ventilation holes in the covers and bottoms matching the air channels. These containers therefore block the circulation when loaded in the 7-wide stabilizing layers.

The top layer, however, may be tightly stacked 7-wide from side wall to side wall. This not only gives lateral stability to the load but also forces cool air from the blower to flow over the load to the rear of the truck where it can pass down over the last stack of containers to enter the longitudinal channels through the load, as shown in figure 5. If the channels between the rows are left open at the top, a large part of the circulating air will settle downward through the load before reaching the rear of the load (fig. 6). Some mechanically refrigerated trailers have ceiling ducts to carry the cool air to the rear. These ducts help to prevent the cool air from short-circuiting the rear part of the load. When ceiling ducts are used, many truckers have found that they are able to maintain somewhat better temperatures on loads of mixed precooled and nonprecooled fruit when the top layer is loaded only 6-wide, leaving the air channels open at the top. Row alinement is then maintained by

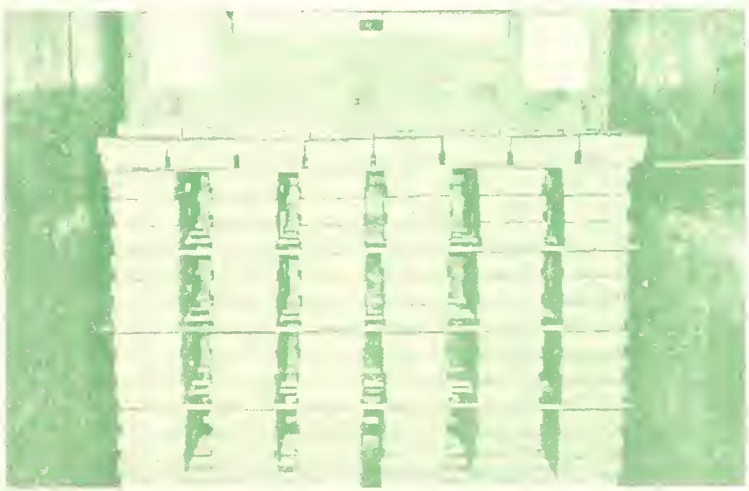


A

BN-11716

B

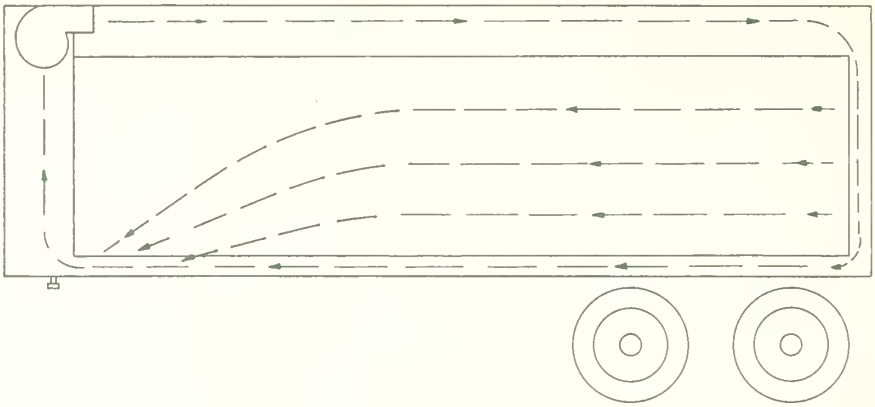
BN-11717

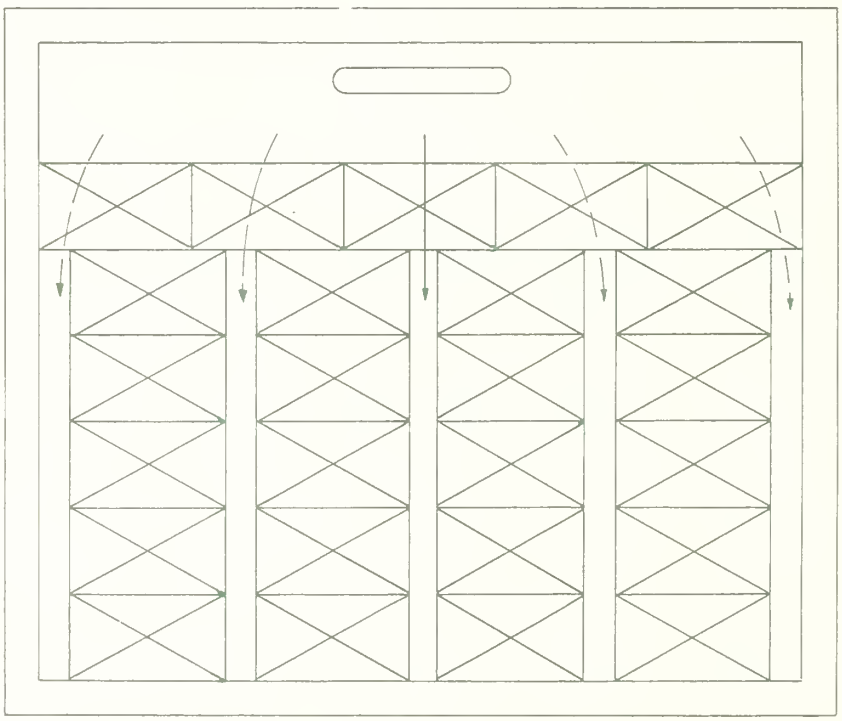


C

BN-11718

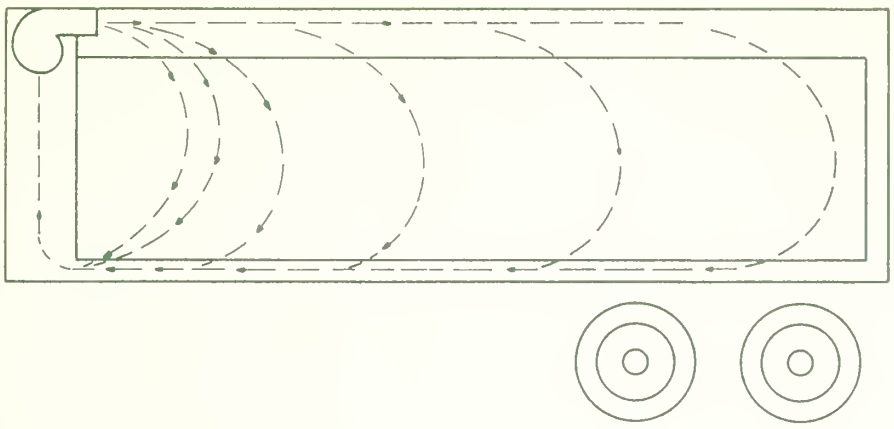
Figure 4.--Improved loading pattern for a mixed shipment of avocados in three types and sizes of containers consisting of less-than-truckload lots consigned to different receivers or different markets: (A) Wooden avocado flats, (B) 4/5-bushel fiberboard avocado and lime box, (C) lime pony flats.

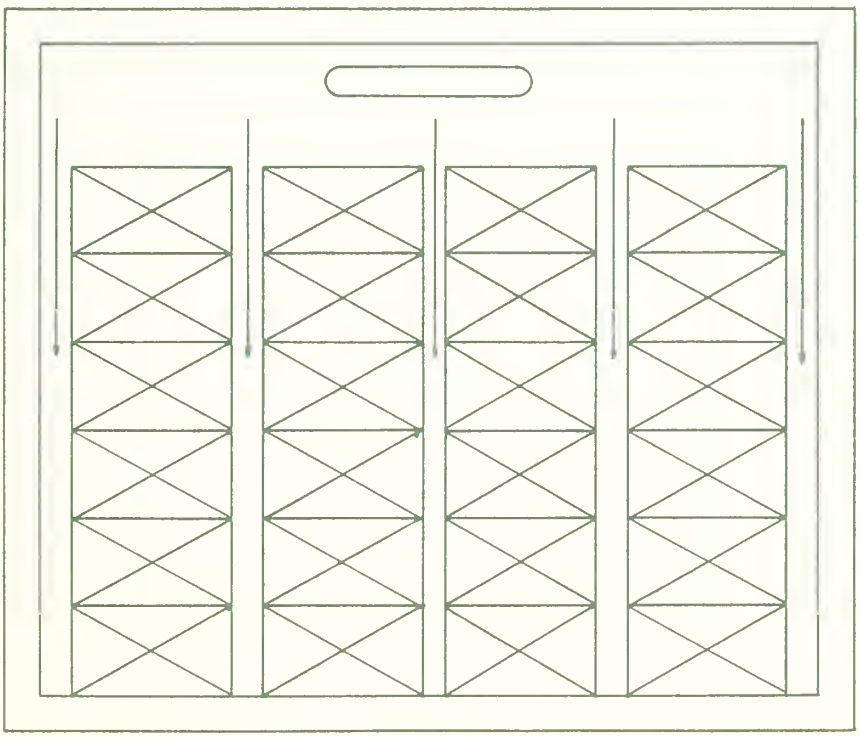




TOP LAYER TIGHT TO SIDEWALLS FORCING ALL CIRCULATING AIR TO REAR BEFORE RETURNING TO BLOWER.

Figure 5.--Air movement inside refrigerated trailer with capped load. Tightly stacked top layer forces cooled air from refrigeration unit at front of trailer to flow to rear of load where it can enter continuous longitudinal channels through load for return to front of vehicle.





TOP LAYER OPEN, ALLOWING CIRCULATING AIR TO RETURN TO BLOWER VIA SHORTEST ROUTE.

Figure 6.--Air movement in refrigerated trailer with non-capped load. Absence of tightly stacked top layer permits cooled air from refrigeration unit at front of trailer to short circuit much of load at rear of trailer.

crosswise strips on the layers, although the containers will often shift unless the driver is particularly careful. Uniform distribution of refrigerated air over all the load is somewhat more difficult to accomplish, however, when the channels are left open at the top than when they are capped with a 7-wide top layer.

The lime ponies shown in figure 4 lend themselves well to this pattern even though the air channels are quite wide and some loading space is sacrificed. However, because of their different length they cannot be placed in the same stack as the flats or 4/5-bushel boxes without leaving slack. They must either occupy an entire stack or be placed on top of the other containers. This situation points up the need for a change in the outside dimensions of the lime pony to correspond with the dimensions of the avocado flat and fit into the previously described modular unit. It would then be possible to load different containers in the same stack to accommodate less-than-truckload orders.

The containers should never be loaded all the way to the rear of the trailer. At least 6 inches of cargo space should be left between the last stack and the rear doors so that the air may complete its circulation down over the rear of the load and enter the openings of the longitudinal air channels at this point. Here again, if the rear doors are stripped, as the side walls should be, some space will be left between the rear of the load and the doors if the load should shift tight against them. To insure that the load will not shift backward, blocking this vital space, and to prevent damage during transit, the load must be secured at the rear of the trailer. The tendency of the containers to shift crosswise out of row alinement and block the longitudinal ventilation channels is greater at the rear of the load than at any other point in the trailer. To prevent this movement at the rear the regular crosswise stripping on every fourth layer should be nailed across the rear faces of the last 3 stacks. Figure 7 shows a good job of stripping on the rear stack of wooden avocado flats.

Wood strips cannot be used on the rear stack of fiberboard containers as these containers cannot be nailed. There are several other effective methods which can be used singly or in combination, such as pressure-sensitive tape, adhesives, or inflatable dunnage bags. When tape is used, it should be placed in double strips from top to bottom and extend back across the top of the load for about 2 feet. At the floor, the tape should be tucked under the box or wrapped around the floor rack. Several types of adhesives are available for unitizing the rear stacks of fiberboard containers. One of the most practical is a high-shear low-tensile-strength glue. Fiberboard containers bonded together with this kind of adhesive can be easily separated at unloading time without defacing their surface.

Inflatable dunnage bags can be placed between the ceiling of the truck and the top of the rear stacks to maintain a light but constant downward pressure on the load which effectively holds the containers in row alinement. The cigar-shaped bags are most practical since they can be placed lengthwise of the truck so as not to block the flow of refrigerated air over the top of the load. Light wooden strips must be placed across the top of the rear stacks so that the downward pressure exerted by inflatable dunnage is distributed equally over all containers in the rear stacks. Very few trucks are equipped with commercial inflatable dunnage bags. Many truckers transporting eggs regularly use one or

A

BN-11719

B

BN-11720

Figure 7.--Rear stack of improved loading pattern showing air circulation channels between rows of wooden avocado flats and use of vertical, horizontal, and diagonal wooden strips to maintain row alinement. (A) Test Shipment No. 2 after loading at shipping point. (B) Same shipment upon arrival at destination market.

two old truck tire inner tubes to prevent the load moving at the rear of the trailer. Because of their shape, however, the inner tubes partly block the circulation of air over the load at this critical point.

Some type of vertical tie-down should be used on every load to help reduce damage and disarrangement of the load from severe vertical vibration, which is especially common on trucks with a long overhang behind the tandem axle. In addition to the preceding methods, some truckers have tie-down systems of their own design or use commercial load-locking devices which do a good job.

To prevent backward shifting of the load, commercial load-securing devices should be locked firmly in place immediately behind a wooden frame placed tightly against the face of the rear stack to keep the entire load in place (fig. 8). If equipment of this type is not available, a brace of 2" x 4" lumber, extra floor rack, or old pallets can often be substituted to fill in the space between the rear of the load and the doors without completely blocking the airflow at this point.

Transit Test No. 1

Load Pattern

The first transit test was the control shipment. It was loaded in what avocado shippers considered to be a good pattern. Longitudinal air channels were left open through the entire load, which consisted of four less-than-truckload orders. Most loads shipped do not have air-channel patterns of this type, but a special effort was made to supply a sample of the best loading pattern in use at that time for the control shipment. The entire loading operation was allowed to proceed without interference from the observer and no recommendations were made to the shipper or the loading crew.

Figure 9 shows the stacking pattern that was followed in loading the vehicle with avocado flats and 4/5-bushel boxes. Six rows of containers and seven air channels formed the basic pattern. In order to give the load lateral stability and eliminate the need for crosswise strips on the layers, an extra flat was placed in every fourth or fifth layer, making that layer 7-wide and in tight contact with the trailer side walls. In the stacks of the 4/5-bushel boxes a seventh container was placed to correspond with the vertical position of the seven avocado flats in adjacent stacks. The rear stack was placed in position with unnailed horizontal wooden strips on every third layer, but no vertical or diagonal strips were used. A 6-inch space was left between the rear door and the load where an extra section of floor rack was placed in the center to help eliminate rearward shifting.

Load Shifting

Six hours after departure an inspection was made at the rear of the load, which was found to be disarranged and damaged as shown in figure 10. At destination this shifting was found to be primarily in the last two or three stacks. Slight shifting was noted throughout the remainder of the load, but it was insignificant. Many of the longitudinal air passages were partially or fully blocked, reducing or completely nullifying their effectiveness for refrigeration.

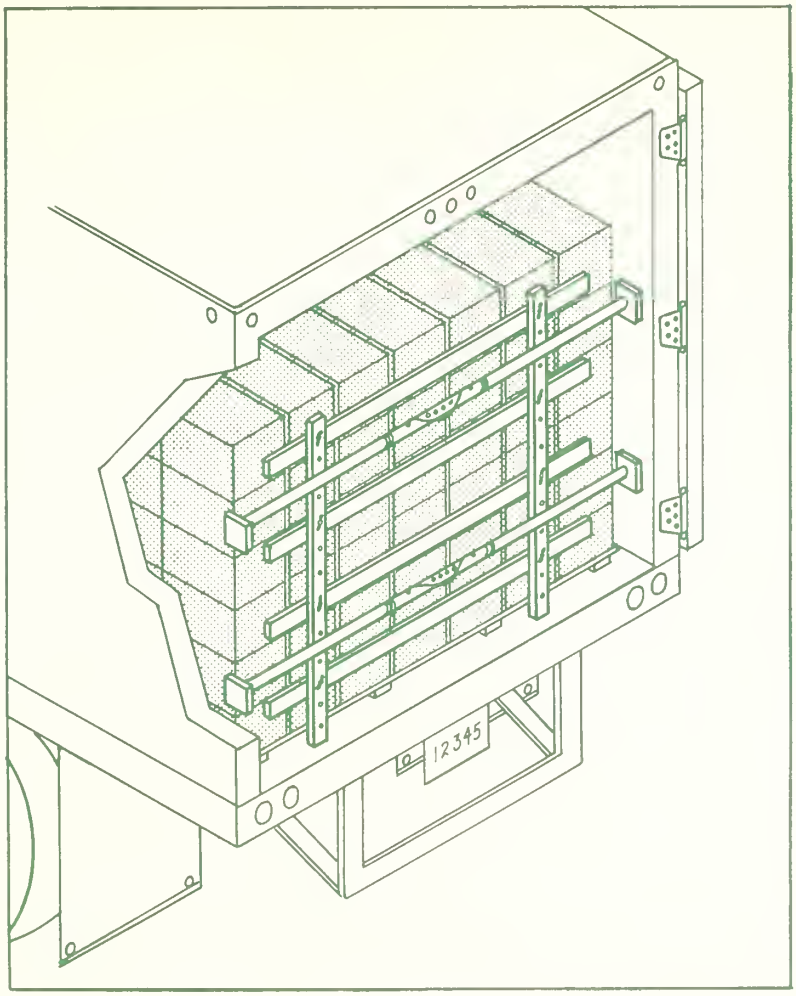
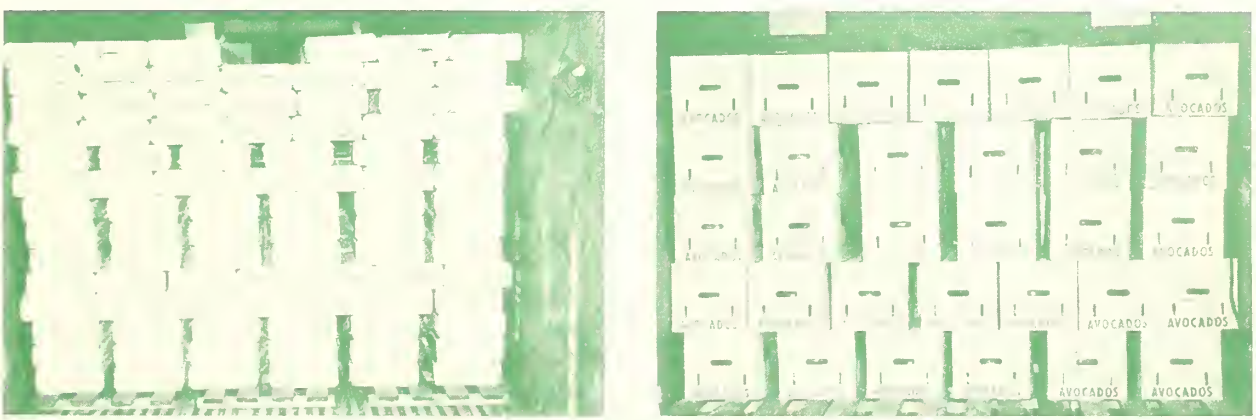


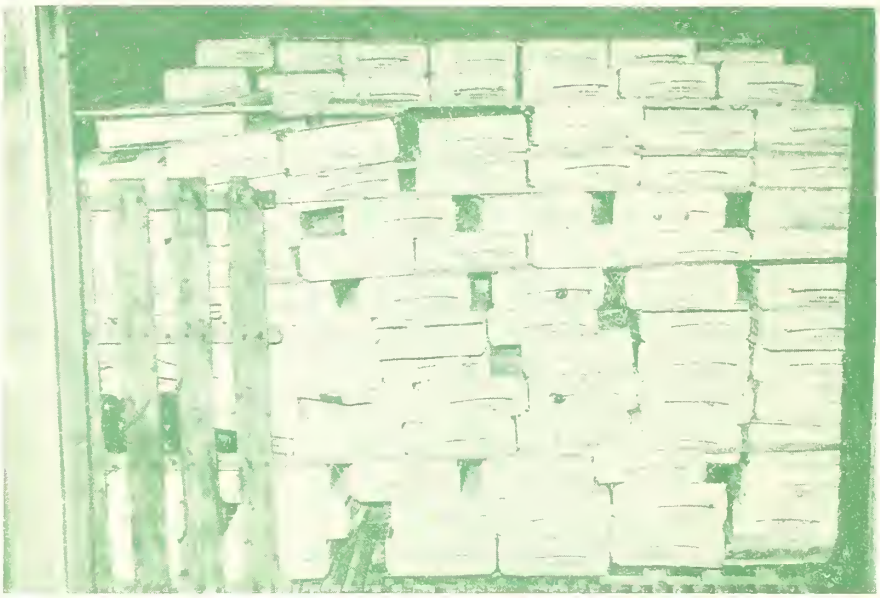
Figure 8.--Friction-type expandable wall braces and gate in place to prevent rearward movement of cargo.



A BN-11721 B BN-11722

Figure 9.--Loading patterns used in control shipments of avocados: (A) Avocado flats in middle of trailer after loading, (B) 4/5-bushel fiberboard avocado and lime box at front of trailer after loading.

These results demonstrated the need for more adequate stripping and nailing of the strips to the wooden flats in the rear of the load to prevent lateral shifting of the containers.



BN-12083

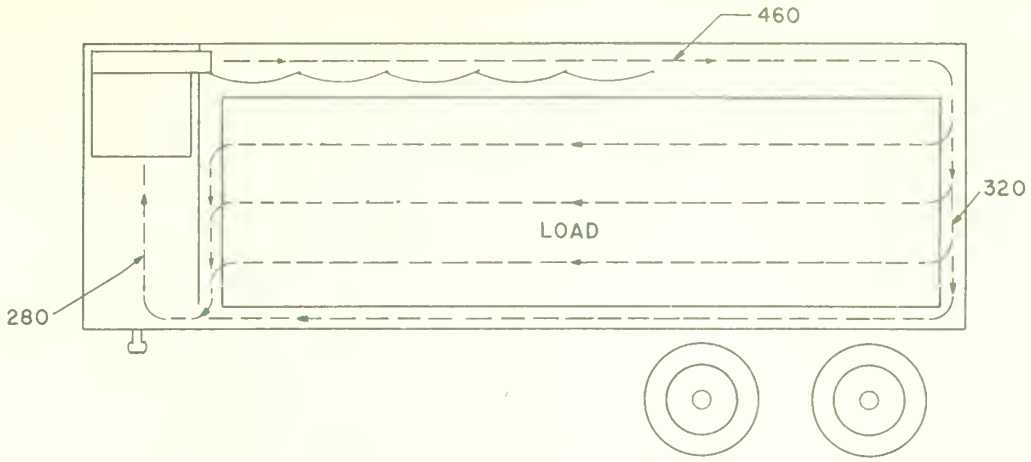
Figure 10.--Rear stack of avocado flats in control shipment after 6 hours in transit showing shifted containers and blocked air circulation channels.

Airflow

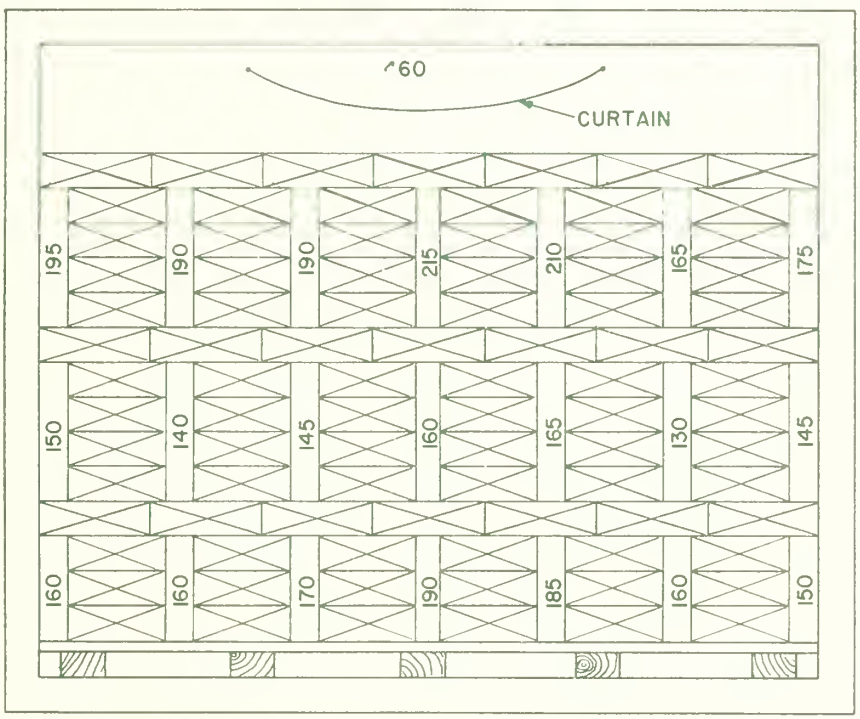
Air movement inside the trailer was measured with a vane-type anemometer. Before the channels were blocked, good circulation was found around the perimeter of the load as well as through the center. Figure 11 lists the airflow in feet per minute at various locations in the trailer. After the load shifted, the flow rate around the load was slightly reduced, although still adequate. The flow through the various channels, however, was so diverted and restricted that it was inpossible to obtain a measure of it. This reduction in circulation resulted in inefficient use of the available refrigeration and subsequent lack of uniformity in product temperature.

Temperatures

Fruit pulp temperature was the criteria by which the effectiveness of the stacking pattern and other practices were rated for their ability to provide the proper environmental conditions. At loading time the average pulp temperature was 63° F. This was gradually decreased during the first 12 hours to 45° F.; in the ensuing 4-day period after the initial cool-down the average fluctuated from 41° to 49° F. (fig. 12 and table 1). Individual readings taken at the same time from various locations within the load showed a spread as high as 25 degrees with an average range of 21 degrees. This wide spread in fruit



SIDE VIEW OF TRAILER SHOWING VELOCITY AND DIRECTION OF AIR FLOW.



CROSS SECTION OF TRAILER SHOWING VELOCITY OF AIR FLOW THROUGH LOAD.
NOTE: FIGURES SHOW AIR VELOCITIES IN FEET PER MINUTE.

Figure 11.--Air movement inside trailer at beginning of control test shipment. After the load shifted, circulation through center of load was almost eliminated.

From Princeton, Fla. to Boston, Mass., Oct. and Nov., 1959

COMPARATIVE TEMPERATURES OF AVOCADOS
DURING SHIPMENT BY MOTORTRUCK

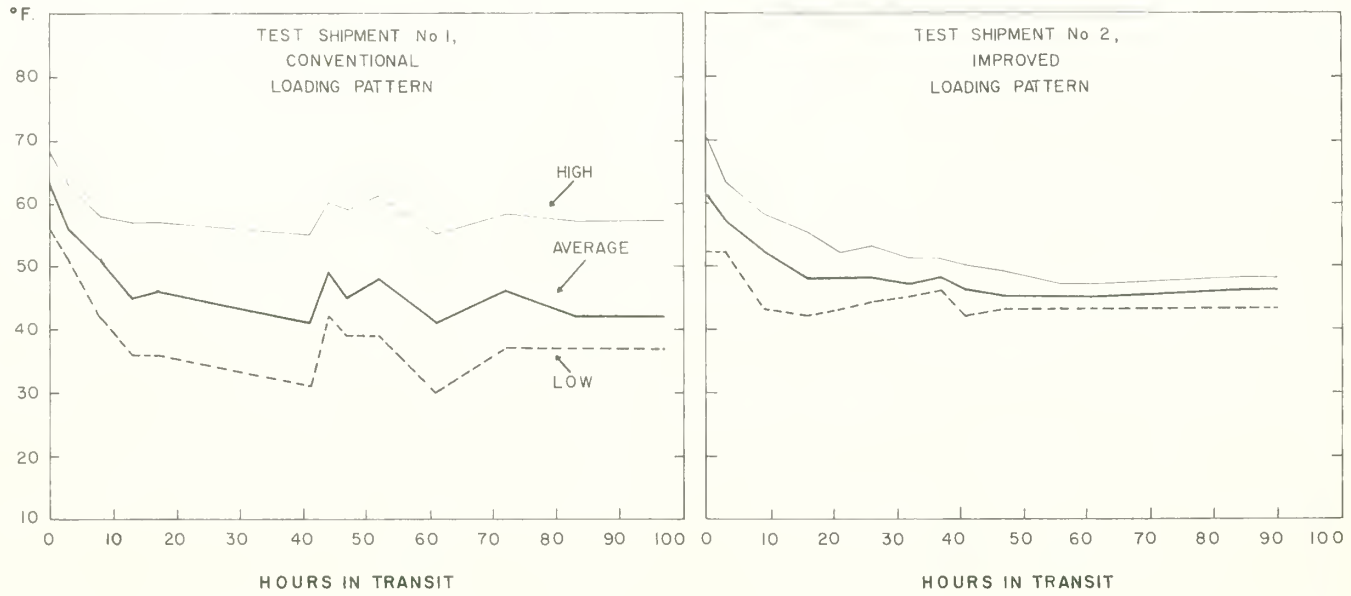


Figure 12.

Table 1.--Pulp temperatures of avocados in motortruck shipments from Princeton, Fla., to Boston, Mass., by type of load pattern, October and November 1959 1/

Test No. 1. Conventional load pattern 2/				Test No. 2. Improved load pattern			
Hours in transit	Commodity temperature			Hours in transit	Commodity temperature		
	Average	High	Low		Average	High	Low
	° F.	° F.	° F.		° F.	° F.	° F.
Loading..	63	68	56	Loading..	61	70	52
3.....	56	63	51	3.....	57	63	52
8.....	51	58	42	9.....	52	58	43
13.....	45	57	36	16.....	48	55	42
17.....	46	57	36	21.....	48	52	43
3/.....	--	--	--	26.....	48	53	44
41.....	41	55	31	32.....	47	51	45
44.....	49	60	42	37.....	48	51	46
47.....	46	59	39	41.....	46	50	42
52.....	48	61	39	47.....	45	49	43
61.....	41	55	30	56.....	45	47	43
72.....	46	58	37	61.....	45	47	43
83.....	42	57	37	85.....	46	48	44
97.....	42	57	37	90.....	46	48	44

1/ From 20 different load locations in each shipment.

2/ Supplementary pulp temperatures taken by pocket-type thermometers at time of unloading showed temperatures as high as 70° F. in 7-wide 4/5-bushel fiberboard boxes.

3/ Temperature instrument temporarily out of order.

temperature shows that fruit in certain load locations was chilled while that in other parts of the load was overheated. This fluctuation in temperature and the wide spread between highs and lows at the same reading demonstrate the effects of impaired air circulation. Pulp temperatures of some individual fruits not having thermocouples in them were as high as 70° F. upon arrival at northern markets.

Delivery Condition

At delivery time all of the wooden flats were accepted by the consignees, although some from the rear stacks required recoopering. There were no complaints registered by the consignees about the temperature variation of ± 5° from the desired 50° F. level as there was little sign of ripening or overheating damage to the fruit in the wooden flats. Some of the 4/5-bushel fiberboard boxes were also delivered with the fruit in good condition and with only slightly higher temperatures than that in the wooden flats. However, the avocados in about 20 percent of the 4/5-bushel fiberboard boxes had pulp temperatures of 65° - 70°. In each case the boxes in the 7-wide stabilizing layers yielded the highest readings, whereas fruit in boxes in the adjoining layers stacked 6-wide

showed little sign of overheating. The last delivery made from the load included 250 fiberboard boxes, 10 of which contained dead-ripe fruit, 42 soft-ripe fruit, 81 ripe, and 117 firm-ripe. The 52 boxes of dead-ripe and soft-ripe fruit were dumped, and the 81 boxes of ripe fruit were salable at a reduced price on the day of arrival only.

In this particular shipment the ripened and overheated fruit were a direct result of the 7-wide tight stacking and the shifting of the load at the rear which blocked air circulation. Fruit in the containers in the 6-wide layers was originally of the same quality and received the same treatment as that in the 7-wide layers. All other transit conditions were identical, except that ventilation holes on the sides of the boxes in the 7-wide layers were blocked while those in the 6-wide layers were exposed to the air channels. Had the air channels not been blocked at the rear of the load more uniform temperatures and less fruit ripening could have been expected throughout the entire load.

Transit Test No. 2

The second transit test incorporated most of the points discussed in the section on "Development of improved loading patterns." These changes were made to correct the deficiencies of the load pattern used in the control shipment, Test No. 1.

Loading Pattern

The stacking patterns employed in this shipment for each type of container are shown in figure 4. The containers in the 6-wide layer were bordered by seven longitudinal channels that were completely open from front to rear with no obstructions to the circulation of refrigerated air. The top layer was tightly stacked against the side walls for added stability of the load. In addition, capping the top of the load with one 7-wide layer also forced air from the refrigeration unit to flow over the top of the load before it could return to the refrigeration unit via the longitudinal channels through the load. Horizontal wooden strips were used on every fourth layer throughout the load to increase lateral stability and maintain row alinement. In addition, the rear stack was also vertically and diagonally stripped as shown in figure 13. All of the strips on the rear stack were well nailed so that, in effect, the entire stack became one large unit. A 6-inch space was left at the rear to provide for circulation of air down over the rear of the load. Two extra sections of floor racks were nailed in this space so they could not move during transit. When loading was completed, a flashlight beam directed through all of the channels revealed continuous open passages to the bunker bulkhead at the front of the load.

Load Shifting

Periodic inspections at the rear of the load during transit revealed no load shifting. Rows and stacks remained in alinement to final destination. Figure 7(A) is a view of the rear stack at the shipping point showing the load pattern upon completion of loading and the stripping applied to maintain this pattern. Figure 7(B) is a view of the load three days later at destination after the truck had traveled 1,500 miles. The slight shift is insignificant and did not restrict air circulation.

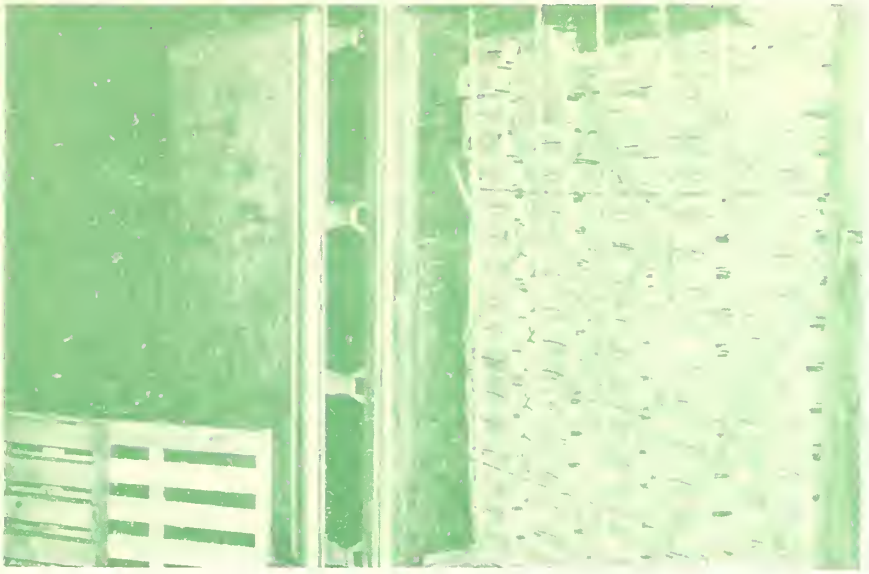


Figure 13.--Rear stack of test shipment at destination with space between rear door and load maintained en route.

BN-12084

Figure 13 is another view of the same load at destination showing the 6-inch space between the rear stack and the door that was maintained en route. The two extra sections of floor racks shown in the lower left of the photograph had been nailed in place to maintain this space.

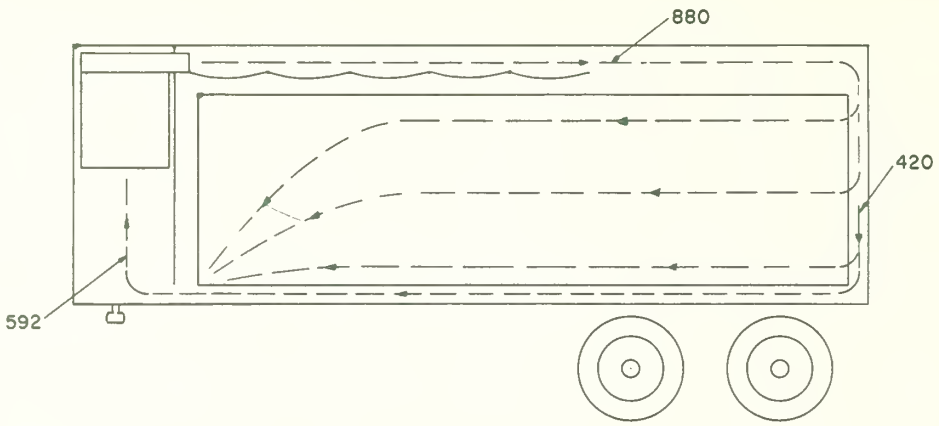
Airflow

Air movement inside the trailer was found to be about the same in this shipment as in the control shipment before the load shifted. Figure 14 shows the airflow measured during the second test in various locations throughout the trailer. Maintaining the original stacking pattern permitted the constant circulation of refrigerated air which resulted in relatively uniform temperatures during the entire trip.

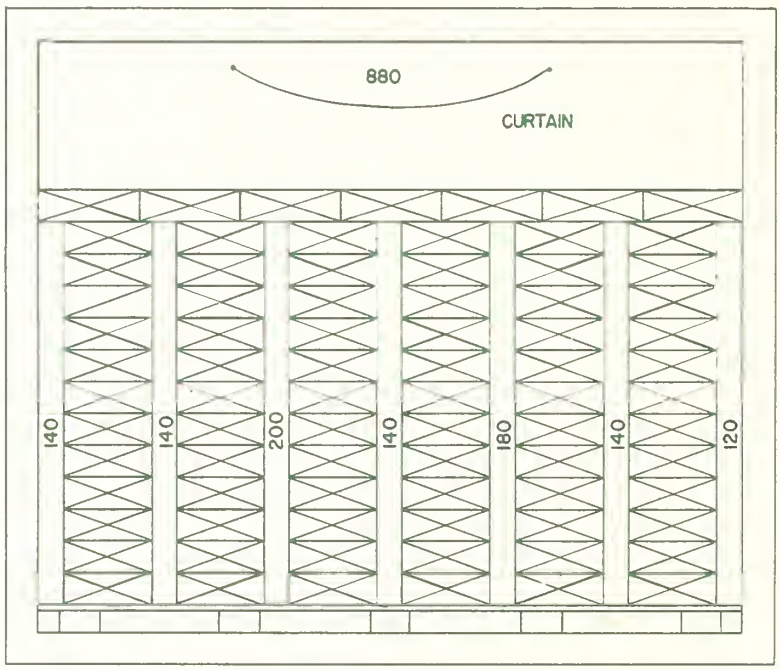
Providing proper airflow over, around, and through the load is essential if effective use is to be made of the available refrigeration. The shipper and trucker should therefore make a special effort at loading time to see that the air channels through the load are not blocked.

Temperatures

At loading time, pulp temperature of the fruit averaged 60° F. After 16 hours, average pulp temperature had been reduced to 48° and during the entire 4-day trip was maintained at a 45° - 48° level (fig. 12). After the initial cool-down, the widest range between individual temperatures taken at the same time was only 9 degrees; the average spread was 6 degrees. This relatively narrow spread in fruit temperatures, shown graphically in the right-hand section of figure 12, demonstrates the effectiveness of maintaining adequate passageways for complete circulation around and through the load. Well braced loads stacked in good patterns will help to insure that uniform temperatures for an entire load will



SIDE VIEW OF TRAILER SHOWING VELOCITY AND DIRECTION OF AIR FLOW.



CROSS SECTION OF TRAILER SHOWING VELOCITY OF AIR FLOW THROUGH LOAD.

NOTE: FIGURES SHOW AIR VELOCITIES IN FEET PER MINUTE.

Figure 14.--Air movement inside trailer during second test shipment. This circulation was maintained during the entire trip.

be maintained. However, it should be remembered that the desired temperature level can only be maintained within the limits of the available refrigeration, whether it be mechanical or ice.

Delivery Condition

Each of the five less-than-truckload orders in this shipment was accepted in good condition as delivered. There were no damaged containers, and pulp temperatures of the avocados were in the 45° to 50° F. range. Samples inspected by each consignee and the AMS observer accompanying the test showed all fruit to be firm ripe.

Following the completion of these shipping tests, the cooperating shipper adopted the new loading pattern and bracing methods for all his truck shipments of avocados and limes. At the close of the 1959-60 shipping season he reported the almost complete elimination of container damage that results from load shifting and disarrangement, and little or no losses in individual loads from overheating and overripening of his fruit.

CONCLUSIONS AND RECOMMENDATIONS

Improved loading patterns and better methods of securing the loads against disarrangement and shifting during transit, developed and tested in this research by the Agricultural Marketing Service, will result in improved refrigeration, less overheating and overripening of the fruit, and less container damage in truck transportation of Florida avocados to northern markets. Use of the improved loading pattern mainly involves more care in planning the load and stacking the containers in the vehicle and requires only a very small added cost for light wooden load strips or glue.

The load pattern developed in this research provided for adequate clearance between the rear face of the last stack of containers in the load and the inside surface of the rear doors and for continuous ventilation channels between the rows, which extend the entire length of the load. The containers were effectively held in row alinement in transit by: (1) Nailing crosswise strips on the layers of wooden avocado flats, throughout the load, (2) nailing vertical and diagonal stripping to the rear stacks of wooden avocado flats, and (3) capping the 6-wide channel load with a 7-wide top layer of containers in tight contact with the side walls of the vehicle. Rearward shifting of the load was prevented by placing two entire sections of wooden floor racks between the last stack of the load and the rear doors.

Periodic inspections of the load during transit and upon arrival at northern markets showed little or no disarrangement or shifting. Temperatures of the fruit, taken periodically in 20 different locations in the load during the entire trip, showed rapid initial cooling of the fruit and adequate maintenance of fruit temperatures throughout the load. Inspection of the fruit upon arrival at northern markets showed it to be firm ripe, with no overheating or overripening. In contrast, the control shipment of the same variety of fruit from the same packinghouse to the same markets in an identical trailer loaded in the best conventional pattern then in use showed considerable load shifting, disarrangement and blocking of air circulation channels, considerable higher fruit temperatures in transit, and overheated and overripened fruit arriving at market.

The following recommended practices for loading and transporting avocados and limes by motortruck based on this research and on research with truck transportation of other perishables will help to prevent damage to container and commodity during transportation, reduce spoilage, and lengthen shelf life of the fruit:

1. Containers for both avocados and limes should have common outside dimensions to permit stacking containers in patterns that will facilitate the flow of refrigerated air.
2. Mature green fruit should be packed, cooled, and shipped as quickly as possible.
3. In precooling before shipment, the stacking arrangement in the cooler should permit circulation around each box for faster and more uniform cooling.
4. Combining precooled and nonprecooled fruit in the same load should be avoided.
5. Handling at loading time should be planned so as to avoid as much heat pick-up by precooled fruit as possible.
6. The truck's refrigeration equipment should be in good working condition and be adequate to maintain desired fruit temperatures in transit.
7. The trailer floor should be clear of all debris and dirt that may interfere with air circulation underneath the load. Floor racks are more effective for this purpose than grooved metal floors.
8. The trailer should be precooled for about an hour by running the refrigeration unit with the doors closed before loading is begun.
9. A curtain over the rear door opening will help to prevent loss of cool air from the trailer during loading.
10. Suitable stacking patterns of the same type developed in this study should be used to provide uniform circulation through the entire load.
11. The load should be adequately stripped and braced to maintain the row alinement and to prevent shifting. This is particularly important on the rear stack.
12. The load pattern should be planned to provide a 6-inch air space between the rear face of the last stack and the inside surface of the rear doors. Some method of bracing the load at this point to maintain this space in transit should be used.
13. Suitable temperatures must be maintained in transit to retard ripening and spoilage of the fruit.
14. The rear of load should be inspected frequently during transit to detect and correct shifting of the load and blocking of air circulation.
15. Pulp temperatures should be taken occasionally where the fruit can be reached, to verify adequacy of refrigeration.
16. "Cowboy"-type driving practices which cause load shifting and product damage should be avoided.
17. Wherever possible the truck should be parked in the shade during in-transit stops in hot weather.
18. When split deliveries are made, the rear stacks in the remaining part of the load should be stepped down and firmly braced to prevent upsetting of unsecured stacks.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1961 O - 584621